Contextual-Analysis for Infrastructure Awareness Systems

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ABSTRACT
Infrastructures are persistent socio-technical systems used to deliver different kinds of services. Researchers have looked into how awareness of infrastructures in the areas of sustainability [6, 10] and software appropriation [11] can be provided. However, designing infrastructure-aware systems has specific requirements, which are often ignored. In this paper we explore the challenges when developing infrastructure awareness systems based on contextual analysis, and propose guidelines for enhancing the design process.

Author Keywords
Infrastructure, Awareness, Contextual Analysis.

ACM Classification Keywords
D.2.1 Requirements/Specifications: User-centric Design

INTRODUCTION
Infrastructures are persistent socio-technical systems over which services are delivered. Infrastructure systems can be physical, e.g., power cables or gas pipes, or human, e.g., home schoolers and gate-community dwellers [8, 9]. One of the most salient characteristics of infrastructure is their invisibility as studied by Star [12]. The invisibility of most types of infrastructures makes it difficult for users to understand their complexity, cost, and environmental impact. Chalmers studied these problems and their impact on appropriation [3].

Some authors have proposed design guidelines for appropriable infrastructures [2, 9, 5]. However, for the question of supporting appropriation (among other things) of already existing infrastructures a different approach has been taken, and a series of systems that seek to provide *infrastructure awareness* have been developed, e.g., Snowdon's CWall [11]. Sustainability projects also make use of infrastructure awareness to foster both reflection among users and more environmentally friendly behaviors [7, 6, 10].

The design of infrastructure awareness systems benefits from contextual analysis as observed in the Imprint project [10] as well as in our own projects. However, we also faced difficulties in translating results from contextual analyses and user-centric design methods to the design of infrastructure awareness systems. Building infrastructure awareness systems does not necessarily require to create new functional features, but rather to design for inducing a certain state of conciousness and optionally supporting social dynamics between users. During our design process, we discuss here three challenges when using contextual analysis for informing infrastructure awareness systems: *nimbus and focus, domain models, and metaphors*.

BACKGROUND
Our work on infrastructure awareness is grounded on two ongoing projects: Cleanly and GridOrbit. They both seek to create awareness of infrastructures that affects both users' everyday life and working conditions. We define infrastructure awareness as *the state of consciousness of a user about one or more properties of an infrastructure*. This definition makes it easier for technology designers to propose different approaches for inducing this state of consciousness in users. It also allows us to define different properties and application areas. An important implication of this definition is that infrastructure awareness can be embedded within the infrastructure, or created through a third party system.

Our first project is *Cleanly*, a 'trashducation' urban system aimed at creating awareness of garbage production and its management. Cleanly serves as an educational platform in the urban environment. As depicted in Figure 1 it includes networked electronic trash bins, electronic badges, and public displays. Our contextual analysis for Cleanly sought to understand people's attitude towards trash in public and private places, and possible solutions to trash misplacement. Our methods included place-centered and task-centered observations, interviews, and a survey. We mainly conducted placed-centered observations at public squares and in random streets of Jerusalem, taking both notes and pictures. We also did sporadic task-observations of people disposing waste and conducted interviews with daily commuters and frequent visitors. We were especially interested in their feelings related to multiculturalism and tourism but also on security and political issues. To get a deeper insight into the trash problem and an indication whether the problems were location-specific or generic, we setup an online survey, collected data during 10 days, and received 139 answers.

Our initial findings suggest that: 1) people have different requirements for cleanliness, 2) cleanliness is related to ownership, 3) people do not care for cleanliness in certain areas, 4) full trash bins trigger further pollution, 4) education, appearance of the bins and their visibility can improve trash habits, and 5) direct feedback for good behavior is encouraging.

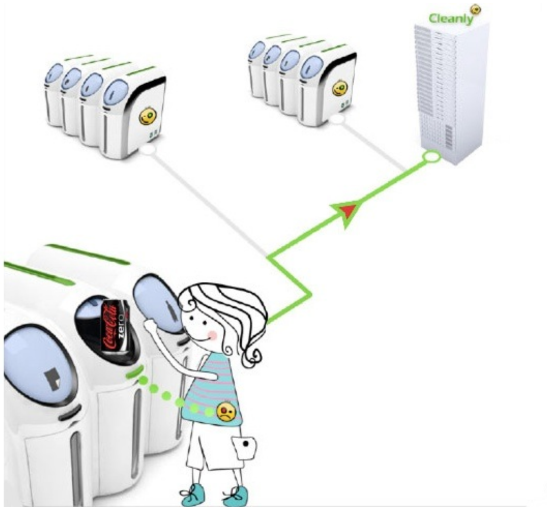

Figure 1. Cleanly's trash bins are equipped with a touch-enabled public display, and RFID and Bluetooth interfaces. This setup allows for tracking users. Users may carry an intelligent (RFID augmented) badge showing the users contribution in the community as a smiley on the badge. The system can build anonymous user models and display information of interest according to location, preferences, and habits.

Our second project is *GridOrbit*, a public awareness display which visualizes the activity of a community grid used in a biology laboratory (Figure 2). This community grid executes bio-informatics algorithms and relies on users to donate CPU cycles to the peer-to-peer grid. The goal of GridOrbit is to create a shared awareness about the research taking place in the biology laboratory. This should promote contributions to the grid, and thereby mediate the appropriation of the grid technology. Our contextual analysis for GridOrbit sought to understand sharing and collaboration habits for molecular biologists while working in the lab. Our methods included place-centered observations, task-centered observations, and interviews.

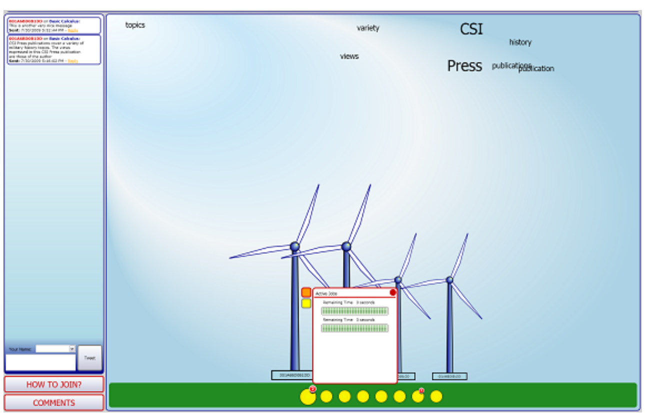

Figure 2. GridOrbit's public display with 3 machines connected.

Our initial findings suggests that: 1) participants worked on specific research problems individually, with low awareness of groups' work, 2) there is extensive sharing of equipment and research material, and 3) researchers use different workplaces for different activities, and they switch from the lab to the office several times a day.

DESIGN CHALLENGES

Our two projects are at different stages of development. For GridOrbit, the contextual analysis team continued the design by conducting participatory design workshops to co-design GridOrbit with its future users. As input to the workshops we created personas, and presented different technologies including awareness solutions and public displays. We decided to work with public ambient displays due to the high mobility of researchers throughout the building. We then created scenarios, sketched paper-based and digital user interfaces, and refined them iteratively. We ran four workshops where we evaluated and improved the current design. Our design artifacts are the personas, situations, scenarios, and prototypes. These artifacts are both annotated and created in each design session. An intangible design tool are the observations and insight gained directly from the users.

For the Cleanly project, we are in an early design stage. We are designing the system based on the existing results of our contextual analysis and a spiral development process. We decided to work with public displays and content personalization drawing from previous experiences in public display and social networking systems. Our design artifacts have been scenarios and prototypes.

Our efforts in the two projects, though different in scope and progress, both deal with creating awareness of infrastructures. We have encountered that we are dealing with a range of similar problems, hence proposing generic solutions for them.

Creating Awareness

Awareness systems define formal awareness models [1], in terms of **nimbus** and **focus**. Nimbus is what an object projects, or what other objects know about it. Focus is what an object is interested in. According to the definition, A is aware of B whenever A's focus intercepts B's nimbus. Awareness systems need to establish an awareness model where the user's focus and the system's nimbus are clearly identified, and they intercept.

However, most systems use *awareness* as a loose notion, do not define an awareness model, and often assume that awareness can be achieved simply by exposing certain properties of a system in both a literal or metaphorical way. We have found that exposing properties of the system is not enough, specially when the users do not have a direct relationship to the various properties of the system. An example of this is the relation of GridOrbits biologists with the P2P grid; biologists did not have a clear mental model of the grid or how contributing power to it would help them carrying out their research.

For GridOrbit we realized that users are not interested in the details of the underlying infrastructure, but they are interested in other research projects going on in the lab. We defined an awareness model where the users' focus includes research projects, progress, and people; and the system nimbus' should match it. Therefore we modified the grid client implementation to gather information about the type and project of the executing tasks in the grid. We then collected this information and showed in the public display as projects and users. The participatory design sessions clearly showed that users understand the grid in terms of projects (not of CPU cycles contributed) and we are preparing for a long term deployment of the public displays to test these representations.

In designing Cleanly, and based on the previous experience, we set out to determine the users' focus from the beginning. We interviewed users and ran a survey regarding possible reasons and solutions of the trash problem, and type of feedback that would encourage more environmentally friendly habits. We found out users were less interested in the reasons of trash in contrast to ways of solving it. We defined an awareness model where the users' focus is their contribution to a cleaner environment and how they stand in comparison to other users, and general information about green-habits. We also included a high interest for community information, not necessarily related to trash. We are therefore designing Cleanly for collecting information about the individual's contributions by building user models and a user generated content distribution platform. The interface will show trends in personal green-behaviour and comparative information to other people/neighborhoods.

As a conclusion, infrastructure awareness solutions should *make explicit nimbus and focus choices*. Users' focus can be elicited through contextual analysis methods, such as interviews and observations. The design process should create the system's nimbus in a way such that it matches the users' focus. This implies moving from the literal elements of the infrastructure to the ones matching the users' focus, e.g., not talking about CPU cycles in a P2P grid, but about projects and users.

The Usage of Metaphors *(or getting the message through)*
Metaphors are commonly used in ambient information system as non-obtrusive ways of concealing information. Examples range from Jeremijonko's dangling string [13] for displaying network traffic to consolvo's flowers garden [4] for encouraging exercising.

In designing GridOrbit we sought to develop a metaphor that would engage biologists in using the grid. We explored with users different types of visualization such as games and trivia but finally developed a visual metaphor based on a windmill farm and light-bulbs. Each computer in the community grid is represented as a windmill, and the contributed CPU cycles are mapped to the rotational speed of the windmill. Each project the researchers work on is represented as a lightbulb, connected to the array of windmills, and the CPU cycles used are mapped to the glowing intensity of each lightbulb. First, we wanted to bind the representations of power and electric consumption, a concept already understood by the biologists. Second, the tech-savvy users are confronted to a different perspective on community grids, one that talks about power instead of devices and protocols. We are still iterating on the representation and plan to explore a more literal one in the months to come.

We chose the wind-farm metaphor and presented it during a participatory design session. During this session the metaphor was throughoutly explained and it appeared to be understood by all participants. However, we noticed problems once we run the next design session; users didn't remember the meaning of the on-screen objects, the concept of *project* had different meaning for everyone, and some others didn't see how windmills and lightbulbs related. Our interviews with users showed that there are three different states: the actual infrastructure, the way users understand it, and the system's metaphorical representation of it.

We see the gap between the actual infrastructure and the users' understanding as an educational issue, which infrastructure awareness systems might not be able to elicit alone. Designers should thus focus on closing the gap between the users' understanding of infrastructure and the system's representation.

Defining a metaphor encompasses different strands that should be incorporated into the design process. During contextual analysis, designers should identify information that help people to pursue their daily activities in relation to the infrastructure. For example, while working on GridOrbit we looked at ways in which researchers organize their electronic and physical files, and how they worked with software suites, and how these could integrate with a community grid. Designers should balance the different interests of future users (their focus) and define the dimensions of the system that will be displayed (system's nimbus) in this regard. Finally, early tests can outline the implications of metaphors and what are the salient dimensions (hopefully the ones the designer had in mind) or the ones that were lost in the design.

As a conclusion, *metaphors have to be widely understood, and the concepts represented should mean the same for everybody*. In an iterative process contextual analysts should identify candidate notions in relation with the infrastructure in question, designers should share, and elicit metaphors, with users. Finally, metaphors should be validated with users outside the design team.

Domain Models
Domain models are a common practice within software development. Software designers tend to define the domain model according to the user interface components and the supported interaction. In infrastructure awareness systems this means the domain model is made up by the concepts in the awareness model and the metaphor. For example in our GridOrbit project, the first domain model was defined in terms of machines, windmills, projects and light-bulbs. This system oriented domain model proved an obstacle when the model of awareness or the metaphor were changed. In subsequent iterations we divided the domain model into levels, where the bottom level followed the elements of infrastructure literally (machines, tasks, jobs, etc) and top levels added abstractions to support both the awareness model and the metaphor. We conclude then that *domain models for infrastructure awareness systems should be made faithfully to the infrastructure*, and that the other elements elicited through contextual analysis be added as upper levels in the model.

CONCLUSIONS

In this paper we have discussed some challenges arising while moving from contextual analysis to the design of infrastructure awareness systems: awareness model, domain models, and metaphors. We have also suggested solutions that can be incorporated within contextual analysis methods: infrastructure awareness solutions should make explicit nimbus and focus choices, metaphors should be widely understood and its concepts mean the same for everybody, and domain models should be made faithfully to the infrastructure.

Despite the mentioned challenges related with creating infrastructure awareness, which is a mental state of a user, short iterations of contextual analysis and participatory design seem to be the only way to carry out design in this field. This statement is founded in the difficulty to determine the user's focus and to test awareness systems, and the understanding of metaphors suitable for a target group.

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BIOS

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